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# SNOW ROAD CONSTRUCTION TECHNIQUE BY LAYERED COMPACTION OF SNOWBLOWER PROCESSED SNOW

M. W. Thomas, et al

Naval Civil Engineering Laboratory
Port Hueneme, California

August 1973

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17

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Elevated high-strength snow roads are constructed over the deep snowfields in Antarctica between McMurdo Station and the Williams Field complex to move cargo and personnel in rubber-tired vehicles. The purpose of this experiment was to simplify the existing techniques developed by the Naval Civil Engineering Laboratory (NCEL) for constructing these snow roads. To achieve this objective, new cutterheads were installed on the ski-mounted snowblower, the pulverized snow was deposited and spread in 4-inch layers which were compacted by walking the area with LGP D-8 tractors. This modified procedure is described as it was performed in the field, followed by a recommended outline for future snow road construction. This new method eliminates the special ski-mounted snow mixers, a savings of both costly equipment and construction time. Test results show that the experimental snow road densities and shear strengths compare favorably with those of previous roads built by pulvimixing. The experimental test section held up under two months of wheeled traffic, proving that snow roads built by the new construction technique will give satisfactory service.

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DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)

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ii

TABLE OF CONTENTS

## INTRODUCTION

Heavy-haul wheeled transportation equipment requires high-strength snow roads for movement of cargo and personnel between McMurdo Station and Williams Field over the Ross Ice Shelf. Present methods, developed by the Naval Civil Engineering Laboratory and used by the Naval task forces for constructing snow roads, required the use of special low-gear LGP D-4 tractors and towed, ski-mounted snow mixers. These methods are detailed in the Snow Road Construction and Maintenance Manual.* The procedure requires that the proposed roadbed be elevated 30 to 36 inches above the surrounding snow surface, leveled, and processed with two towed snow mixers. This effort is time-consuming since the snow mixers travel only 60 feet per minute. Also, both the tow tractors and ski-mounted snow mixers are costly, special equipment. Based solely on the factors of construction time and equipment cost, it was considered desirable to devise a more simplified procedure for constructing snow roads.

After examination of each step of the present construction technique, it was decided to investigate a method of layered compaction of snowblower-processed snow as a substitute for the mixing process. The layered compaction method consists of: (1) depositing snow on the roadbed by a ski-mounted snowblower; (2) leveling the snow into 4-inch layers with a towed snowplane; and (3) compacting the snow by walking the area with LGP D-8 tractors. To recommend this method as a suitable replacement for the mixing process, it was necessary to build a snow road by layered compaction, then compare its density, shear strength, and trafficability to that of pulvimixed roads.

A modification of the snowblower was necessary before constructing the road to provide a processed-snow density equivalent to that of pulvimixed snow. The existing four-blade cutterheads were replaced by new ones with eight blades so that the natural snow would be sheared into finer granules. To alleviate clearance problems that were encountered, the ends of the cutterhead blades near the center drive housing and the external support arms were modified in the field before the cutterheads were installed.

## EXPERIMENTAL PROCEDURES

Once the snowblower was modified, the field plan called for the construction of a one-mile, experimental road during DF-73 by the layered compaction process. The following experimental procedures are presented to outline the actual construction of the field test section.

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*Naval Civil Engineering Laboratory. Snow Road Construction and Maintenance Manual, by W. H. Beard. Port Hueneme, Calif., January 1972.

## Selecting and Preparing Site

A test site near the Naval Support Force, Antarctica, (NSFA) snow road was selected, and alignment and grade stakes were installed according to the Snow Road Construction and Maintenance Manual.* Next, the surface was rolled between the stakes of the roadbed with the eight-foot diameter steel roller, weighted with 2000 pounds of ballast. This rolling gave a fairly uniform, compacted surface for depositing the first layer of blown snow.

## Depositing Containment Berms

The first pass of the snowblower deposited the containment berms along the outer edges of the road. Following cuts 1 and 1A of Figure 1, the snowblower passed along just outside of the alignment stakes, depositing the material inside the stakes as close to the edge as possible. During this initial pass, tests were made to determine the tow speed, depth of cut, and engine rpm which produce the best material. Operating the snowblower at 2400 to 2800 engine rpm, a towed speed of 58 feet per minute, and a cutting depth of 18 inches, the containment berms were 24 to 30 inches high. It was difficult to construct these berms the same height and maintain a straight line.

## Blowing Snow Layers

The snowblower made a pass up each side of the snow roadbed, depositing the snow over the roadbed surface. The intention was to follow the same sequence in the cutting as outlined in the Snow Road Construction and Maintenance Manual,* casting the snow to the middle of the roadbed and spreading it between the centerline and the opposite containment berms. However, the snowblower with its new cutterhead could not blow the snow to the center of the road from the outside cut as specified. Therefore, cuts numbered 2, 2A 5, and 5A, shown in Figure 1, were made leaving only approximately two feet between the inside and outside cut. Tests showed that operating the snowblower in low gear at 2400 to 2800 engine rpm with a 14 to 16-inch cutting depth deposited too much snow, causing problems in leveling and compacting. The snowblower was then operated in high gear with the same engine rpm cutting 8 to 12 inches deep. This operation deposited sufficient snow for leveling and compacting in 4-inch layers. The LGP D-8 dozer towing the snowblower must maintain a constant speed for cutting in high gear. The best towing speed was determined to be approximately 88 feet per minute with the LGP D-8 in low gear at 600 to 800 engine rpm. The towing speed, depth of cut, and the engine rpm must be closely controlled so that the deposited layer of snow will be no more than 4 inches thick after planing or leveling.

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*Naval Civil Engineering Laboratory. Snow Road Construction and Maintenance Manual, by W. H. Beard. Port Hueneme, Calif., January 1972.

## Leveling Snow Layers

After one round trip on each side of the road, the deposited snow must be immediately leveled over the entire roadbed surface. Leveling directly behind the snow plow was attempted using an LGP D-4 dozer with an angled blade (Figure 2), and then with the LGP D-8 dozer with a straight blade, both without success, as this required operator skills not readily found in the construction personnel furnished for this project. Finally, an 80-foot snowplane towed by an LGP D-4 dozer (Figure 3) spread the deposited material over the roadbed in a thin, level layer no greater than 4-inches thick. This method was much better than those previously tried.

## Compacting Snow Layers

To compact the 4-inch layers, an LGP D-8 towing a ballasted 8-foot diameter steel roller made three passes over the entire road surface. The additional roller weight, an increase from 8,000 to 10,000 pounds, caused an unforeseen problem. The weighted roller began to plow the loose, freshly-blown snow until enough resistance would build up, then it would roll over the hump causing an extremely wavy surface. Because of this problem, the rolling operation was eliminated and only three walking passes of the LGP D-8 tractors were used for compacting the snow.

## Constructing Transition Sections

Since the towed, ski-mounted snowblower required at least 200 feet to turn around, transition sections were required at each end of the one-mile road for access to and from the NSFA snow road and to and from the Williams Field complex. These transition areas were constructed by two LGP D-8 tractors: one dozing snow onto the roadbed and the other leveling the snow into 4-inch layers and compacting by walking each layer. The minimum number of passes required for compaction was doubled from three to six since the snow was bulldozed into place instead of being processed and deposited by the snowblower.

## Preparing Finished Surface

After the first layer was blown, leveled, and compacted, these three procedures were repeated for each additional 4-inch layer until the road was elevated 24 to 30 inches above the surrounding snow surface. Once the desired road height of 24 to 30 inches was achieved, the towed 80-foot snowplane was used for finish leveling the surface. After finish leveling, the road was allowed to set up for three days. Then, to surface harden the top four inches, three complete passes over the entire surface were made with the rubber-tired, wobbly-wheeled roller towed by a one-ton pickup. Following the rolling, the timber drag was towed by the same pickup to smooth the road surface. Even after the

wobbly-wheel rolling, swells 2 to 4 inches high caused by the initial rolling operation were still observed over most of the road. To eliminate the swells a rubber-tired road grader was used to level the test section and the transition area to the existing NSFA road. Another pass had to be made with the wobbly-wheel roller and timber drag to compact or remove the loose surface snow caused by grading. Finally, all berms or protrusions along the edge of the road were removed to reduce the drift-in problems. An illustration of a typical, finished road cross section is shown in Figure 4.

## TEST RESULTS

Test cores were taken at selected points at three different times between 5 December 1972 and 2 January 1973 to determine the density and shear strengths of the experimental test section. Since tests were made on each 3-inch core segment, the densities and shear strengths shown in Figures 5 and 6 are the average of six such segments that made up each 18-inch core. The results of all DF-73 cores compare favorably with those obtained in previous testing of pulvimixed and snowblown roads during DF-65.* The densities of the DF-73 test section are 20 percent greater than those of DF-65 snowblown roads, and the shear strength after only two days of sintering is three times greater. After 20 days the shear strengths of both snowblown roads are identical because the aging process tended to stabilize the increase in strength. By comparison with the data on the pulvimixed roads, the density of the test section cores are slightly greater, while the shear strengths of past pulvimixed roads range from 30 to 50 percent greater than those of the DF-73 snowblown test section. It should be mentioned that while aging or sintering affects the strength of the compacted snow, also the season during which the aging takes place is a factor. This phenomenon is evident in Figure 6 by the loss of strength between 25 December 1972 and 2 January 1973 due to the warmer air temperatures and solar radiation causing deterioration of snow particle bonding. To define the season during and after construction, temperature profiles were taken from a thermocouple station set to record temperatures at depths of 1, 10, and 16 inches. These profiles are plotted in Figure 7 for three different time periods.

The road was opened in early December to normal traffic which continued until February. This road constructed by the new method showed no evidence of deterioration from wheeled vehicles. The surface remained smooth and no failure points were found. Loads grossing over 70,000 pounds were carried over the road during this test period.

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*Naval Civil Engineering Laboratory. The Bearing Capacity of Depth-Processed Compacted Snow on Deep Snowfields, by E. H. Moser and G. E. Sherwood. Port Hueneme, Calif., 1965.

## RECOMMENDED PROCEDURE AND EQUIPMENT

Using the new simplified construction methods for high strength snow road construction requires a step-by-step procedure to assure high-quality snow roads. Although some of the procedures are identical to the old method described in the Snow Road Construction and Maintenance Manual,* every step is outlined below for clarification and completeness:

1. Select site, and place alignment and grade stakes so that the roadbed is 33 feet wide.

2. Compact the 33-foot wide roadbed between the alignment stakes with an LGP D-8 and a weighted 8-foot diameter steel roller.

3. Level compacted area with snowplane, and recompact with an LGP D-8 and a weighted 8-foot diameter steel roller.

4. Make initial pass with snowblower depositing material at inside edge of alignment stakes to form containment berms 24 to 30 inches high.

5. Level the containment berms and straighten them to the recommended height of 24 to 30 inches with an angle-blade dozer.

6. Make the next pass with the snowblower depositing sufficient material on the roadbed between containment berms with a level 4-inch layer. The D-8 tractor towing the snowblower should be operating in low gear at 600 to 800 engine rpm and with a forward speed of 88 feet per minute.

7. Spread material in a level, 4-inch layer over the roadbed using a snowplane or road grader immediately following the snowblower.

8. Compact the deposited and leveled 4-inch layer by walking at least three passes over the entire surface with an LGP D-8 tractor.

9. Repeat steps 6, 7, and 8 until road surface is elevated 24 to 30 inches above the natural terrain surface. It is important that depositing, spreading, and compacting <u>each</u> 4-inch layer (steps 6 to 8) be performed and completed during a single, working shift.

10. Finish leveling road surface, and remove any berms at the outer edges of the road with a rubber-tired road grader having reduced tire pressure.

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*Naval Civil Engineering Laboratory. Snow Road Construction and Maintenance Manual, by W. H. Beard. Port Hueneme, Calif., January 1972.

11. After three or four days, roll road with the rubber-tired wobbly-wheel roller to harden the surface for wear resistance.

12. Smooth the finished road surface with a timber drag to eliminate any ridges. After four days, the road should be ready for normal traffic.

The equipment used for this method of snow road construction is available at Williams Field, Antarctica. The ski-mounted, rotary snow-blower is the only piece of equipment that is unique and not adaptable to other construction or operational requirements. Since some steps in the procedures can run concurrently, equipment availability will determine construction techniques and time requirements for the road construction. The following equipment is required for this modified snow road construction method:

1. A tracked personnel and cargo carrier. (Step 1).

2. Two to four LGP D-8's. (Steps 2, 3, 4, 6, and 8).

3. A ski-mounted rotary snowblower. (Steps 4 and 6).

4. An angle-blade dozer - LGP D-4 or LGP D-8. (Steps 3, 5, and 7).

5. A 40-foot or 80-foot ski-mounted snowplane. (Steps 3, 7, and 10).

6. A road grader with reduced tire pressure. (Steps 7 and 10).

7. A rubber-tired wobbly-wheel roller. (Step 11).

8. A one-ton pickup or larger rubber-tired tow vehicle. (Steps 11 and 12).

9. A timber drag. (Step 12).

CONCLUSIONS

1. Snow roads built by this modified method have demonstrated that they will give satisfactory service for the movement of cargo and personnel by heavy, wheeled transportation equipment.

2. The method will reduce construction time by more than 40 percent and eliminate the requirements for expensive, unique ski-mounted snow mixers, special low-geared tractors, and operators' skills not readily available in the construction battalions.

3. Test results have shown that both densities and shear strengths of the experimental snow road section compared favorably with previously snowblown and pulvimixed roads.

## RECOMMENDATIONS

1. Depositing snow layers of <u>only</u> 4 inches or less is the single most important requirement of this new snow road construction method, and this specification should be observed to assure a road for all season.

2. In future construction of snow roads by the layered compaction method, the following steps should be added to the experimental procedures:

a. After the initial compaction of the natural snow in preparing the roadbed, it should be planed level and rerolled a minimum of three passes to insure a level, compacted road base.

b. The containment berms should be straightened and leveled to the recommended height of 24 to 30 inches by an angle-blade dozer.

c. After one or two layers have been completed, a road grader with reduced tire pressures should spread the snowblower-deposited snow into the 4-inch layers. The grader would eliminate the requirement for one additional operator and probably do an even better job than the towed snowplane.

3. Further comparison tests should be run on the densities obtained from the eight-blade versus the four-blade cutterheads to determine if the additional blades are really necessary.

4. To eliminate the special, ski-mounted snowplow and the need for the tow-vehicle operator, the feasibility of using a tracked carrier for the rotary snowblower should be investigated.

## ACKNOWLEDGMENT

The authors wish to acknowledge Mr. W. H. Beard for his consultation on equipment and snow road construction procedures, and Mr. F. W. Brier for his timely advice and assistance during the construction of the experimental snow road.

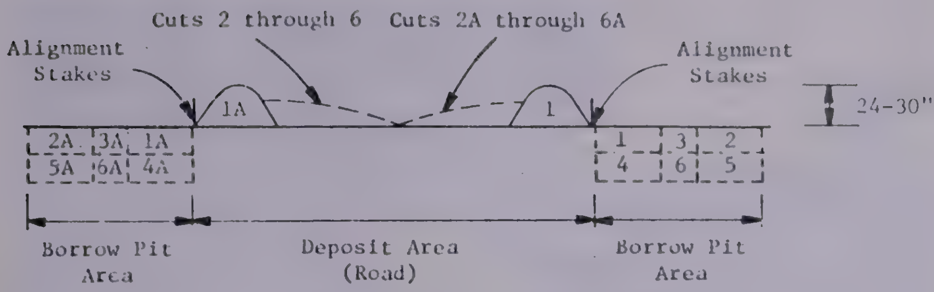


Figure 1. Cross section showing sequence of passes for elevating snow roads with a snowblower.

Figure 2. Leveling with an angle-blade LGP D-4.

Figure 3. Leveling with an LGP D-4 towing an 80-foot snowplane.

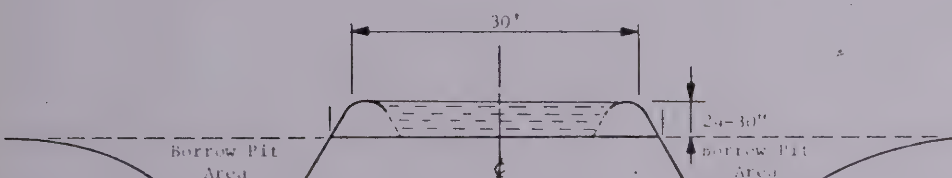


Figure 4. Typical cross section showing finished road.

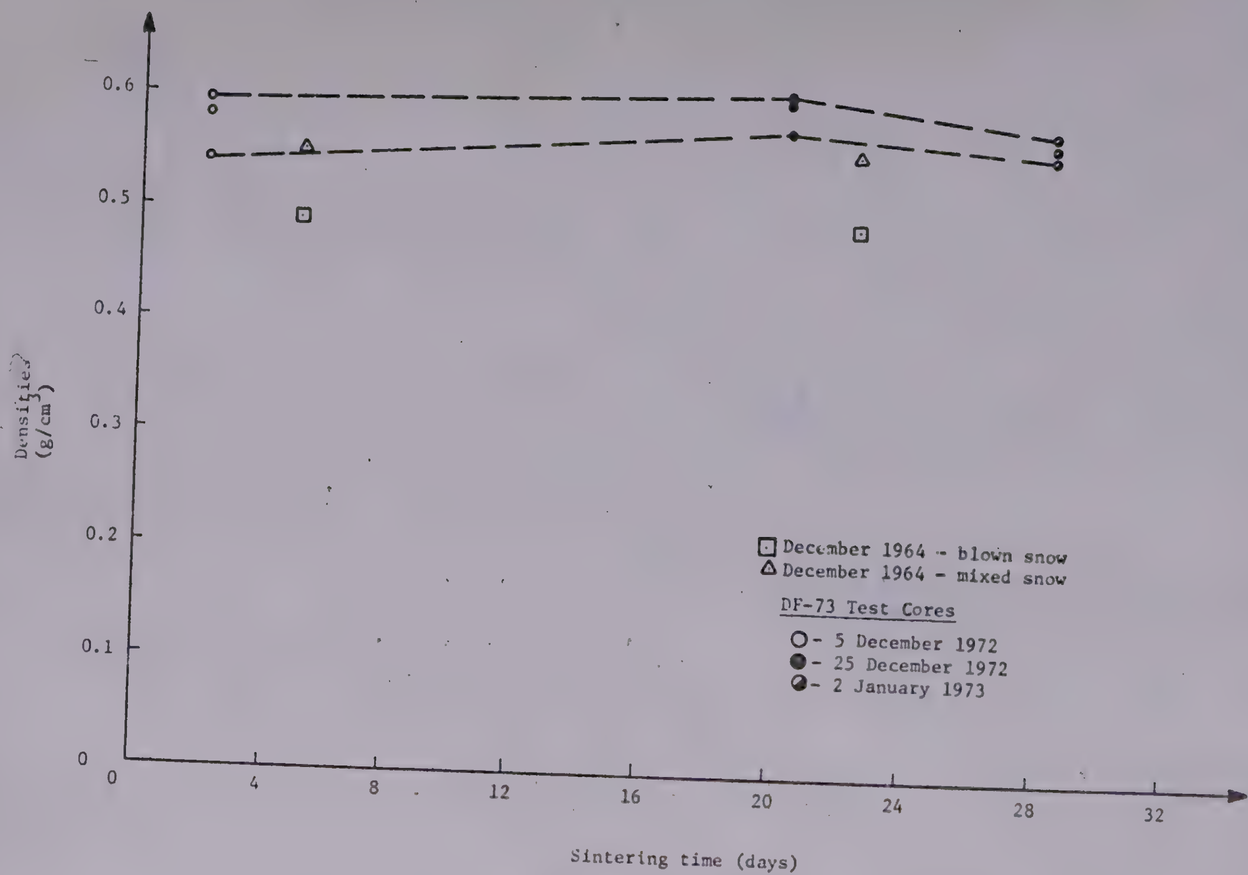


Figure 5. Sintering time versus density for snowblown and pulvimixed roads.

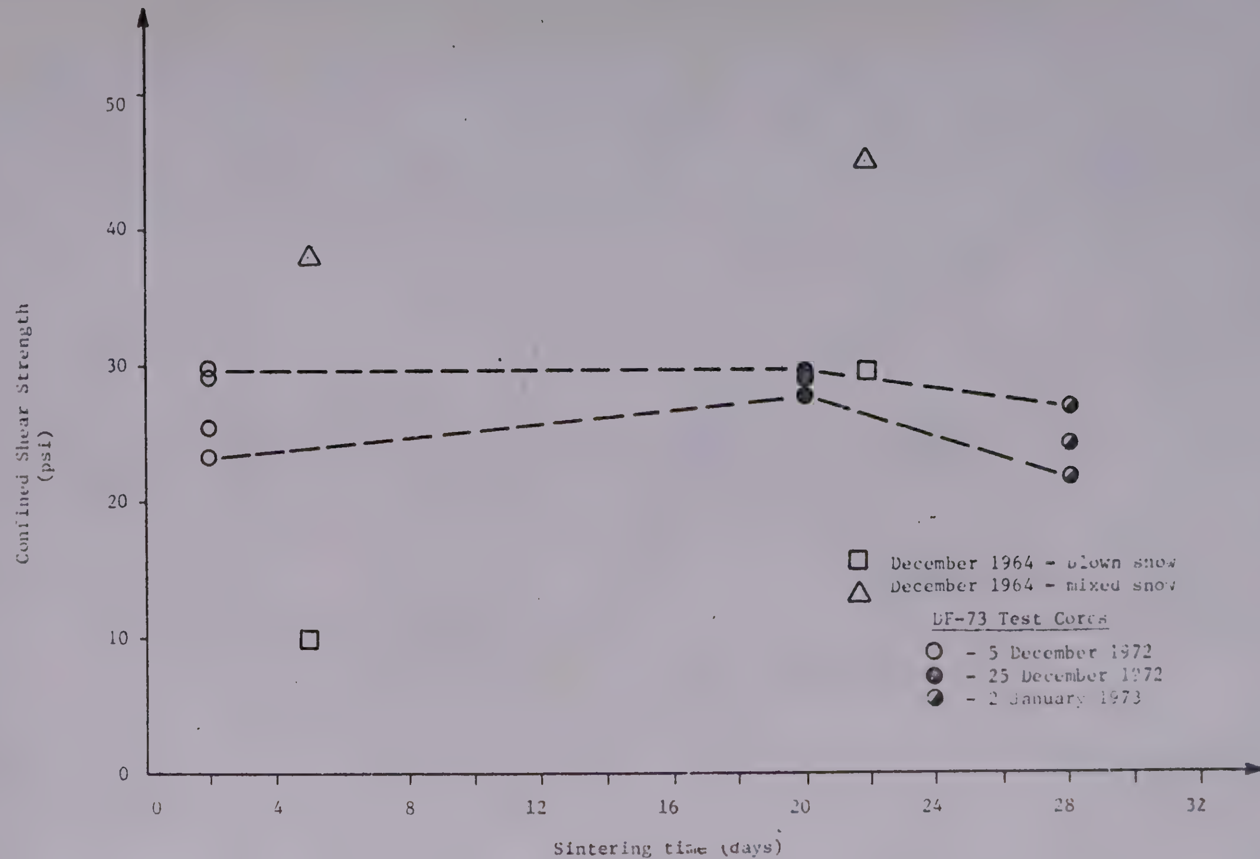


Figure 6. Sintering time versus shear strength for snowblown and pulvimixed roads.

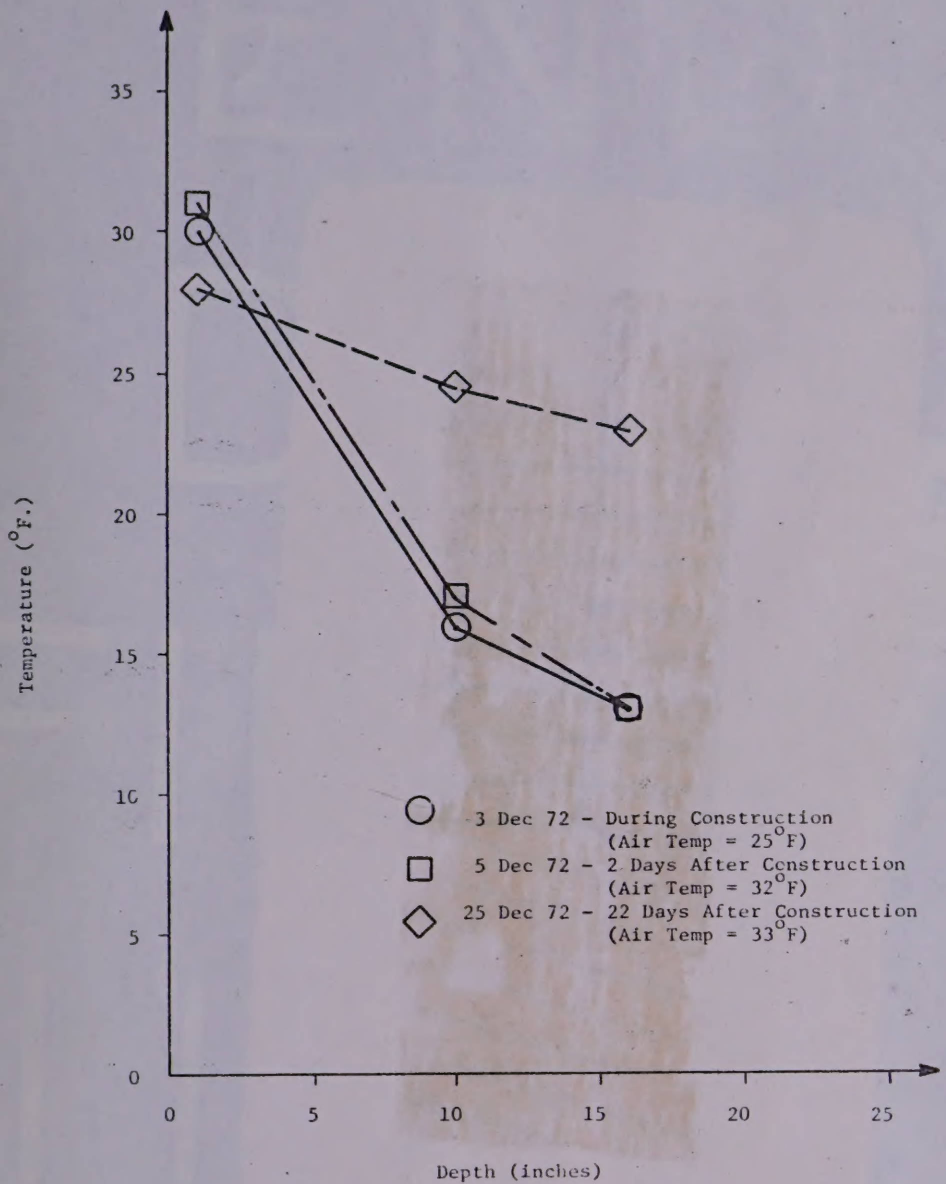


Figure 7. Temperature profiles for three different time periods.

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